Synergy of Using Nadir and Limb Instruments for Tropospheric ozone monitoring (SUNLIT): overview of the project results

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Project objectives

The ESA -funded project (Sep 2018- Dec 2019, ESA Science for Society Open Call) SUNLIT - Synergy of Using Nadir and Limb Instruments for Tropospheric ozone monitoring - is aimed at creating the tropospheric ozone column dataset using combination of total ozone column from OMI and TROPOMI with **stratospheric ozone column** from all available limb-viewing instruments (MIPAS, GOMOS, SCIAMACHY, OSIRIS, ACE-FTS, SAGE-II, MLS, OMPS-LP).

Novelty of the approach is using data from several satellite instruments for estimating stratospheric ozone .

Ozone in the atmosphere

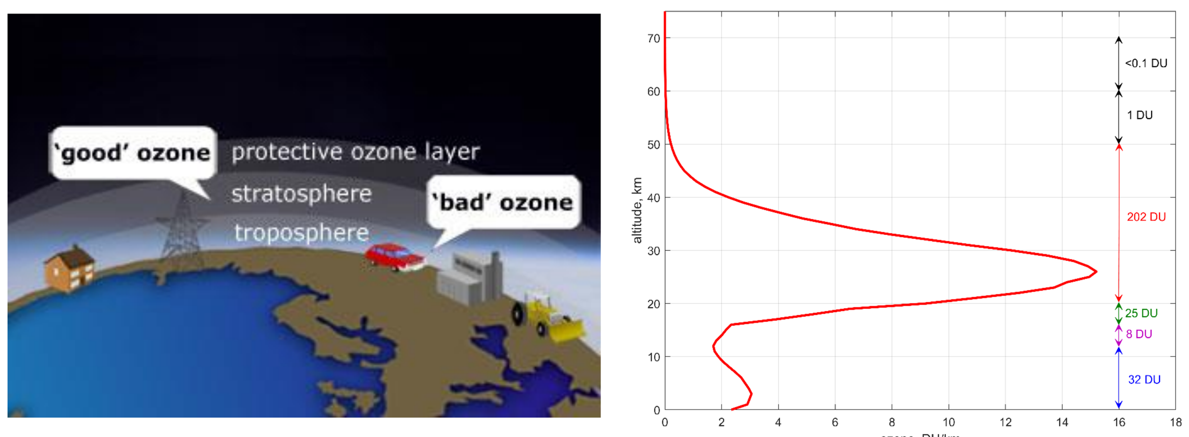

Figure 1: Ozone distribution on the Earth atmosphere.

About 90% of ozone is in the stratosphere (the ozone layer); it protects the life on Earth from harmful UV radiation. The current main issues related with the stratospheric ozone include springtime ozone hole over Antarctica and ozone trends.

Tropospheric "bad" ozone is the atmospheric pollutant: it has toxic effects on human and vegetation. In the upper troposphere and lower stratosphere (UTLS) ozone is a greenhouse gas.

The detailed information about the tropospheric ozone is of high importance, because it is nowadays one of the major environmental concerns. Trends in tropospheric and stratospheric ozone are still under active debates.

Tropospheric column dataset for trend analysis

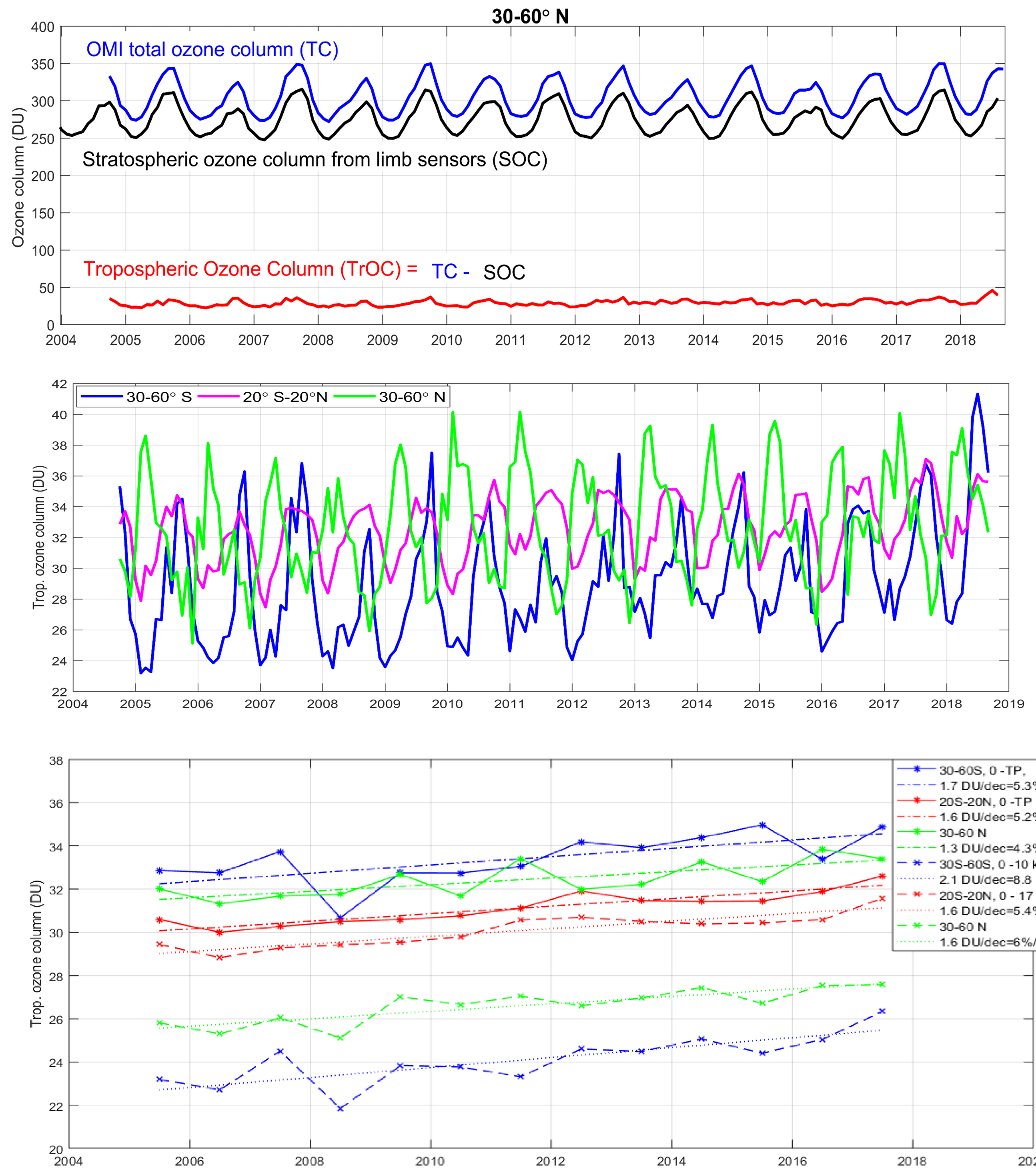

Figure 4. Top: Illustration of the residual method using the data at 30-60N. Center: Time series of tropospheric ozone in three broad latitude bands. Bottom: yearly averaged time series of tropospheric ozone and the fitted linear trends. Altitude and latitude ranges are indicated in the figure.

To study long-term global changes, monthly zonal mean data of total and stratospheric ozone is created.

The total ozone data are from OMI clear-sky observations.

The stratospheric column data set was created as follows. First, the data from 8 satellite instruments - SAGE II, MIPAS, SCIAMACHY, GOMOS, OSIRIS, ACE-FTS, OMPS and MLS – are merged into the dataset on ozone profiles with the same method as applied for creation of the SAGE-CCI-OMPS dataset (Sofieva et al., 2017). This approach ensures the stability and, at the same time, provides the best data quality in terms of different biases.

Then the stratospheric ozone column are obtained by integration of monthly zonal mean ozone profiles.

The tropospheric ozone column climate data record obtained by the residual method, is in very good agreement with ozonesonde and other satellite observations reported in Tropospheric Ozone Assessment Report (TOAR).

The estimated trends are in the range 1.6-2 DU per decade, in full agreement with TOAR estimates.

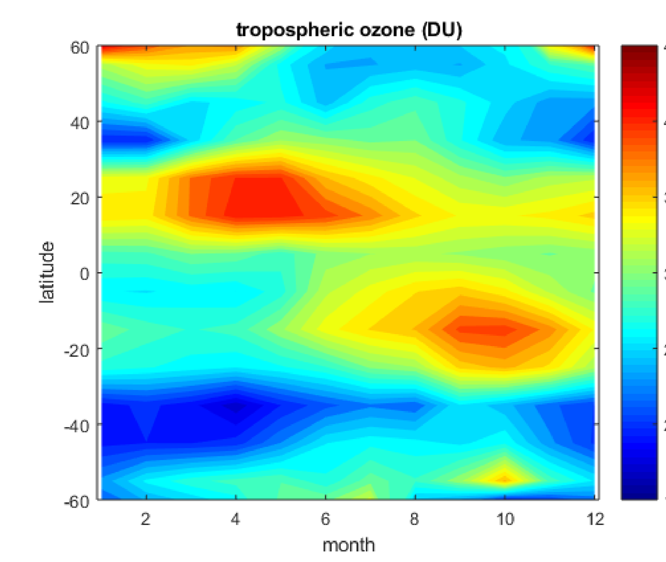

Figure 5: Seasonal and latitudinal dependence of tropospheric ozone

Using SILAM CTM for feasibilty studies

For feasibility studies, we use the chemistry-transport model SILAM (System for Integrated modeLling of Atmospheric coMposition, Sofiev et al., 2015, http://silam.fmi.fi). SILAM is a multi-scale model with seamless scaling from the global coverage down to regional scale with 1-km resolution. SILAM chemical and physical modules cover both the troposphere and the stratosphere.

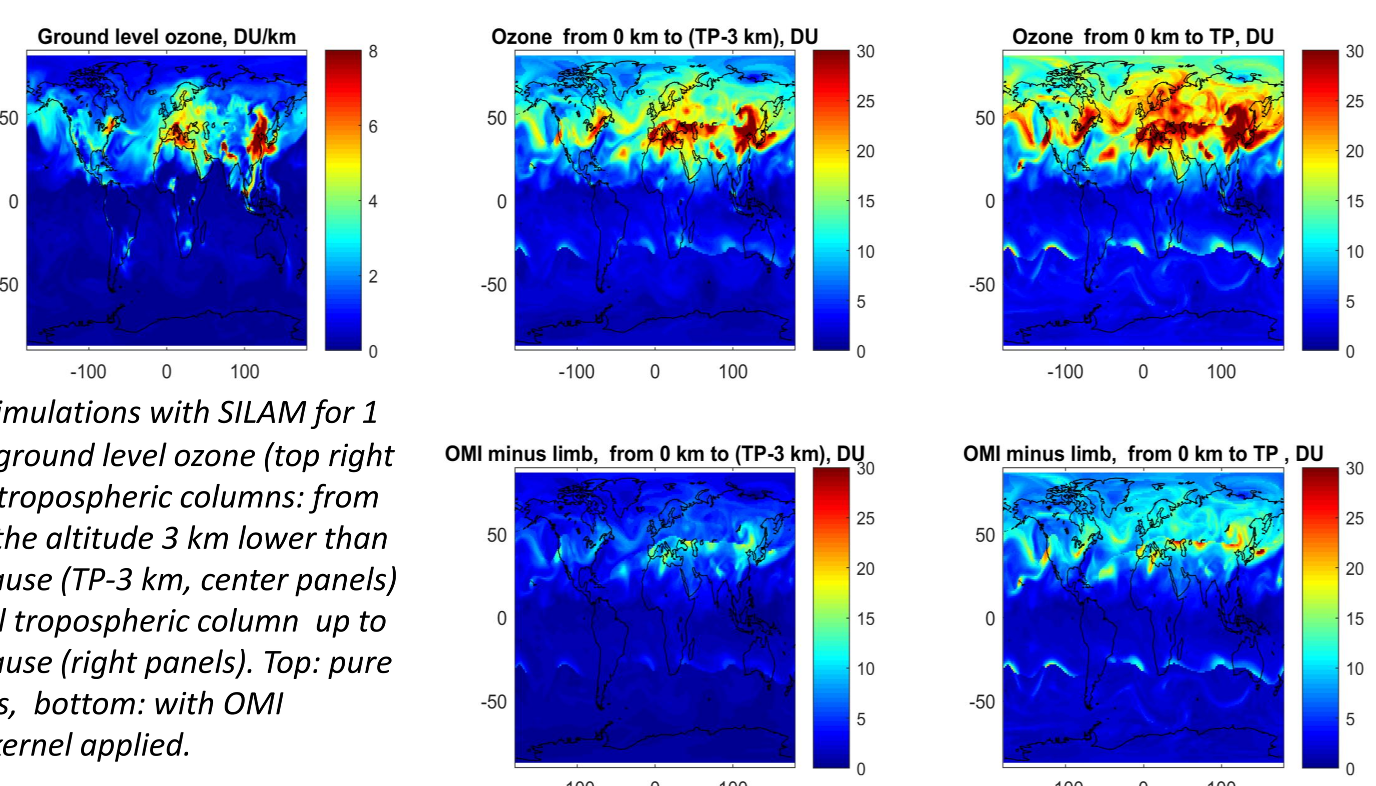

Figure 2: Simulations with SILAM for 1 July 2008; ground level ozone (top right panel) and tropospheric columns: from ground to the altitude 3 km lower than the tropopause (TP-3 km, center panels) and the full tropospheric column up to the tropopause (right panels). Top: pure SILAM fields, bottom: with OMI averaging kernel applied.

For general evaluation of the residual method, we compared ground level ozone with the tropospheric ozone columns observed from combination of OMI measurements with ideally known stratospheric ozone column. In our simulations, we studied also the influence of the OMI averaging kernel. We observe that the tropospheric features are significantly blurred in tropospheric column. The OMI averaging kernel has low sensitivity near the ground, so that the tropospheric ozone column by the residual method is mainly sensitive to the upper troposphere.

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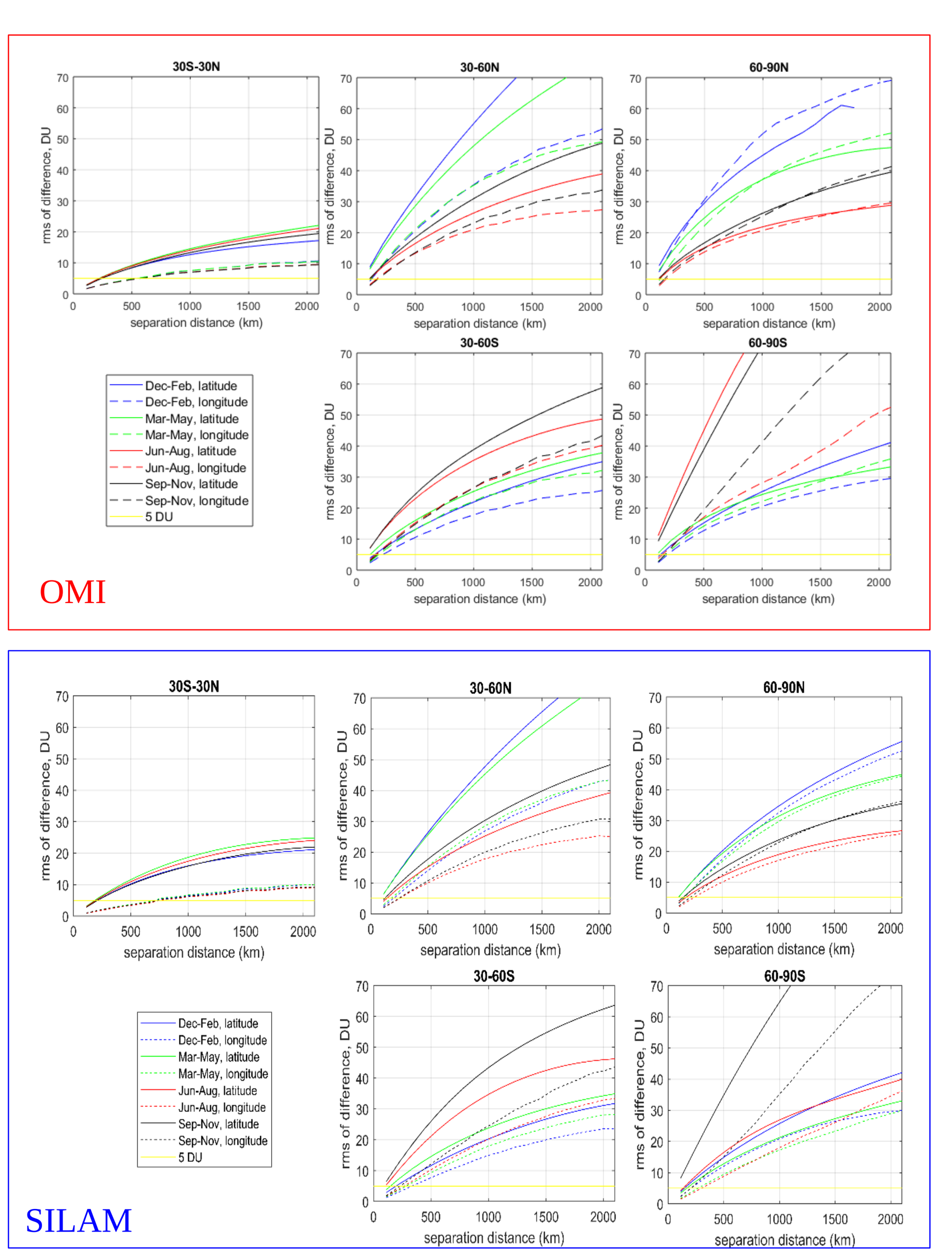

Figure 3: Structure functions of total ozone column evaluated using the OMI and SILAM data in 2005-2012.

Using the SILAM data and OMI data, we analyzed the small-scale variability of the total and stratospheric ozone column data using the concept of the structure functions, i.e.

$$D(\boldsymbol{\rho}) = D(\mathbf{r}_1 - \mathbf{r}_2) = \left\langle \left[f(\mathbf{r}_1) - f(\mathbf{r}_2) \right]^2 \right\rangle$$

We found:

- The morphology of ozone variability is quite expected
- The variability in tropics is overall much smaller than at middle and high latitudes.
- At middle and high latitudes, variability in summer is smaller than in winter.
- The structure function is evidently anisotropic nearly everywhere, except for 60-90 N, all seasons and 60-90 S in March-May.
- In polar regions in winter and spring the ozone variability is very strong, even for small separations.
- The structure functions for total and the stratospheric ozone column are very similar.

This information is important for the developing the methods of stratospheric data interpolation.

Characteristics and intercomparison of limb satellite datasets

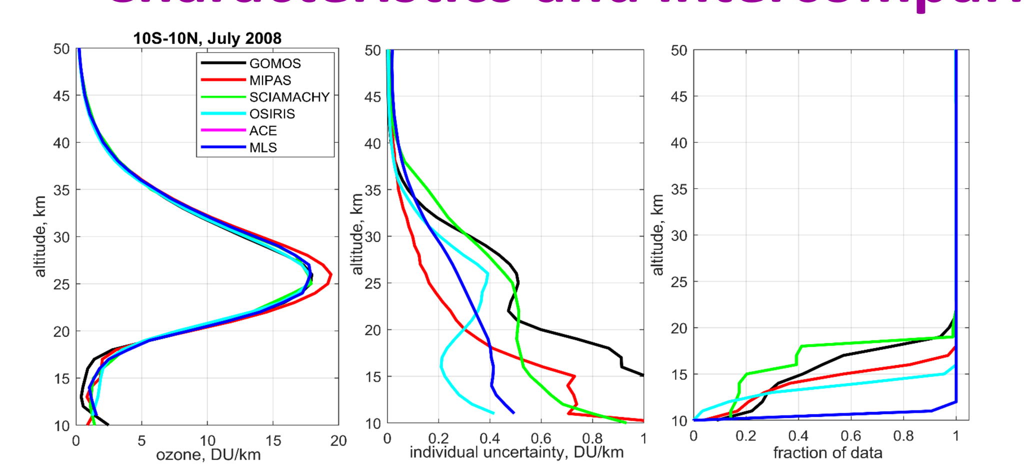

Figure 6: Ozone profiles (left), mean uncertainty od individual profiles (center) and the fraction of total number of data, for 10S-10N in July 2008.

The upper tropospheric ozone constitutes a significant part of tropospheric ozone column. However, coverage and data quality of limb instruments in the UTLS is limited. These issues can be mitigated by data averaging.

In addition, ozone profiles from different satellite instrument have biases, which are in general altitude, latitude and season dependent. To make the datasets compatible, either anomalies can be used (for climate data record) or biases should be explicitly corrected (for detailed distributions).

We found that the optimal way of bias correction is correcting biases of profiles. The biases are estimated using comparison of data in 10° latitude bands, for each months during several years.

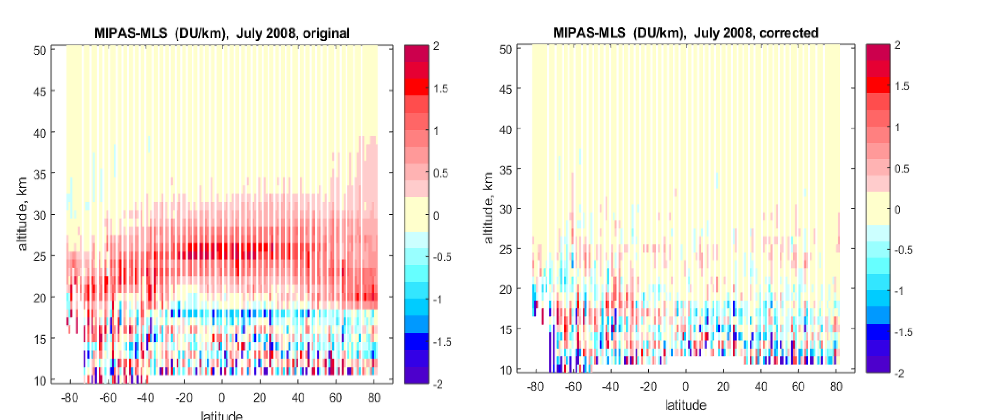

Figure 7: Bias between MIPAS and MLS profiles before (left) and after (right) bias correction

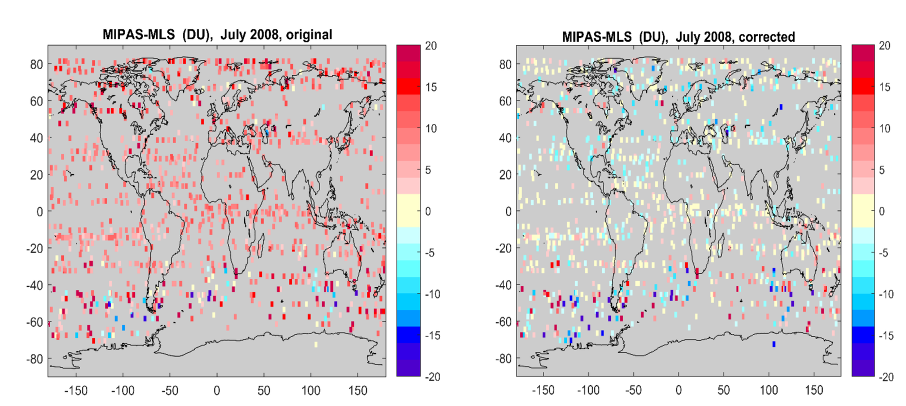

Figure 8: Bias between MIPAS and MLS stratospheric column before (left) and after (right) bias correction

Examples of tropospheric ozone column distributions

The example of tropospheric ozone column for July 2008 is shown in Figure 9. The monthly distribution of tropospheric ozone is computed using daily data. For creating daily stratospheric ozone data, biases between the instruments are removed, and the data interpolation which takes into account the variability of ozone field is applied. The interpolation method was developed using simulated ozone field by SILAM. It is performed sequentially, first interpolation along orbit, and then horizontally in regions of small ozone variations.

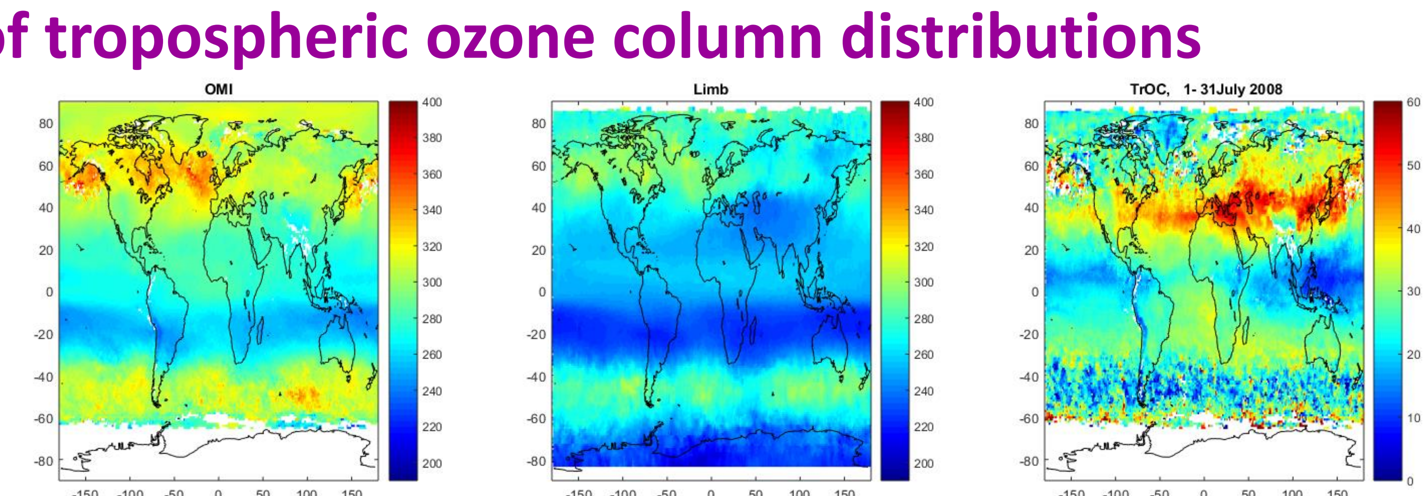

Figure 9: Left: OMI total ozone column for July 2008; center: stratospheric ozone column from all limb instruments; right: tropospheric ozone column computed from daily tropospheric ozone data by the residual method.

The obtained TrOC is very similar to the NASA OMI-MLS data (obtained from https://acd-ext.gsfc.nasa.gov/Data_services/cloud_slice/new_data.html), as seen in Figure 10.

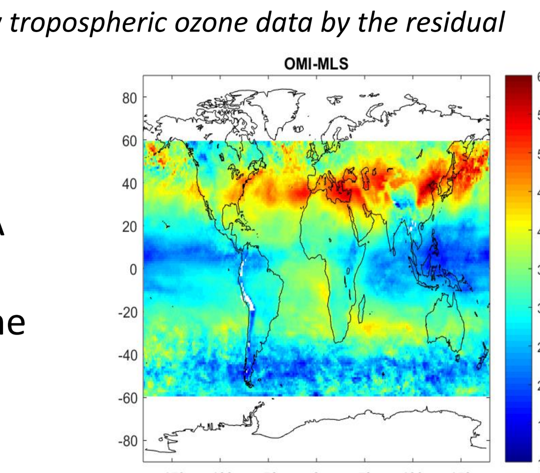

Figure 10: NASA OMI-MLS tropospheric ozone column for July 2008.

Selected references

Gaudel, A, Cooper, OR, Ancellet, G, Barret, B, Boynard, A, et al. 2018. Tropospheric Ozone Assessment Report: Present-day distribution and trends of tropospheric ozone relevant to climate and global atmospheric chemistry model evaluation. Elem Sci Anth, 6: 39. DOI: https://doi.org/10.1525/elementa.291

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Sofiev et al., (2015).: Construction of the SILAM Eulerian atmospheric dispersion model based on the advection algorithm of Michael Galperin, Geosci. Model Dev., 8(11), 3497–3522, doi:10.5194/gmd-8-3497-2015